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To what extent can innovative international project delivery strategies (which leverage BIM) improve the cost certainty of large complex public procurement projects in the context of Irish public procurement?

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Abstract – Cost overrun is one of the biggest issues in the construction sector, and cost certainty is one of the main aims of the public construction sector in Ireland. Studies have shown that multi-disciplinary collaboration will benefit a construction project throughout its lifecycle. BIM, Lean, and IPD are independent methodologies that encourage collaborative work, and there are existent effective synergies among these concepts. The synergetic innovative international strategies were utilised for delivering large complex projects successfully globally, and many authors have studied large complex public projects that have adopted innovative international project delivery strategies collaboratively and have shown that the cost certainty was positively affected. However, this synergetic approach has only been used occasionally in Irish public works projects.

The impact of innovative international project delivery strategies on the cost certainty of large complex public procurement projects will be investigated, and the barriers for implementation in Ireland will be explored. The data was derived from an extensive literature review, key stakeholders of large complex projects that embraced modern construction strategies. They were interviewed to identify the obstacles and issues they faced to utilise the trilateral synergetic strategy. This detailed research resulted in 3 Key Insights: (1) The revision of the Public Works Contracts to be more collaborative and increase trust among the stakeholders (having a form of IPD); (2) BIM Mandate is important to encourage using modern construction methodology in all public projects; (3) Finding innovative methods to change traditional thinking about construction.

The consideration of the 3 Key insights will boost the implementation of the innovative project delivery that leverage BIM; this results in achieving better outcomes in Public Works, in the short, medium, and long terms for all Stakeholders.

Keywords – Procurement; BIM; Lean; IPD; Benefits; Barriers.

I. INTRODUCTION

The Irish public sector has been negatively impacted by the extent of cost overruns in public works, poor distribution of risks and rewards among stakeholders, and limited collaboration between different professions (Stewart, 2015). All professionals working in this fragmented industry need to adapt their working procedures for the industry to return to prosperity (McAuley, et al., 2015).

The digitalisation of the construction industry is introduced to create efficiency and effectiveness in operations in this sector (Aghimien, et al., 2018). Digitalisation is 'spearheading a transformation of the built environment and creating a space where digital and physical built assets interact', Building Information Modelling (BIM) being at the heart of this transformation (Philp, 2016).

The complexity of the construction industry is higher than other industries, thus it needs new theories of construction to support a renewed drive for greater performance improvement. BIM is seen as a proper method for such projects (Ismail, 2019). However, there is concern about digitalisation. A report of the National BIM Council Roadmap to Digital Transition for Ireland's Construction Industry 2018-2021 warns about a risk in case no more collaborative approaches are available to increase work together, which might cause a stalling in a digital transition. Collaboration is essential in BIM (McAuley & Lefebvre, 2019).

It is necessary to know how to approach the digitalisation because it is an important opportunity in

terms of cost certainty (Sategna, et al., 2019). Cost certainty is one of the key objectives which the Irish government set out to achieve by reforming the previous public works procurement (Framework, 2005).

Poor planning and collaboration in construction projects have caused additional unforeseen costs (Stewart, 2015). There were innovative international project delivery strategies (which leverage BIM) introduced in the construction sector as an attempt to increase the efficiency of the building process and boost the alignment among practitioners, thus resulting in greater cost certainty (Stewart, 2015). Such strategies introduced were Lean, IPD, and BIM as an attempt to improve cost certainty and collaborative work (Gaughan, 2015).

It is observed that BIM affects the traditional ways of collaboration and information management in the AEC industry (Ismail, 2018). BIM facilitates the building to be built twice - once in a virtual world, where the constructability issues can be revealed and resolved, then in the real world where the physical building can be flawlessly built. It helps a project to achieve better quality buildings in a cost-effective manner (Philp, 2016). Moreover, Lean is presented to enhance efficiency of project deliver. According to Sacks and many authors, "Lean brings added value to the customer and reduces waste, along with continuous improvements" (Sacks, et al., 2010, p. 968). The collaboration environment is essential in construction projects; Integrated Project Delivery (IPD) is introduced because it seeks to align and integrate all project team members' interests and objectives, thus it motivates the collaborative work (Ismail, 2018).

The innovative international project delivery strategies (which leverage BIM) have made a remarkable impact on the construction industry globally (Stewart, 2015); however, unfortunately they are only occasionally adopted in Ireland.

In this research, the impact of innovative international project delivery strategies on the cost certainty of large complex public procurement projects will be investigated and the barriers for implementation in Ireland will be explored.

II. Research Objectives

1. Objective 1: To critically analyse the impact of the current public procurement in large scale public projects in Ireland on cost certainty.
2. Objective 2: To critically identify the international project delivery strategies (which leverage BIM) including Lean and IPD.
3. Objective 3: To critically evaluate the impact of international project delivery strategies (which leverage BIM) including Lean and IPD on a large complex public project.
4. Objective 4: To critically examine the implementation of the trilateral synergy of BIM, lean and IPD to deliver a large-scale public project in Ireland.
5. Objective 5: To critically appraise the recommendations to address the challenges and problems of objective 4.

III. Research Methodology

In objective 1: Qualitative methodology comprising semi-structured interviews with various stakeholders of public work, along with a thorough literature review of the currently obtainable published material.

In objective 2: Extensive literature review of currently obtainable published material.

In objective 3: Extensive literature review of the currently obtainable published material and thorough assessment of the previous findings along with case study investigation.

Objective 4: Conducting semi-structured interviews with multiple stakeholders working on large complex public projects in Ireland that embraced the innovative international project delivery strategies (which leverage BIM). Participants were selected based on their roles, responsibilities, and experience related to the delivery of the projects they worked on. Therefore, BIM managers, Specialist contracting, and a digital construction operation manager will be interviewed.

Objective 5: A qualitative research method including semi-structured interviews with multiple construction experts, namely project managers and BIM managers.

IV. Literature Review

a) *Public Procurement in Ireland*

Public works represent a large proportion of construction activity in the Irish construction industry and the Irish economy (Gaughan, 2015). For this reason, it is necessary to ensure cost certainty is being achieved in each public works procurement, especially the cost certainty of a large public project, because cost overruns in large projects reduce other investment costs (Reform, 2018). Thus, cost certainty in the public works sector and related investments make possible good government spending (Gaughan, 2015).

In the construction context, cost certainty refers to the construction costs of any particular project. According to Xiao and Proverbs (2003), "cost certainty represents the probability of completing a project within the budget agreed between clients and contractors before the commencement of construction" (Xiao & Proverbs, 2003). Factors affecting cost certainty include the type of contracts, absence of uncertain costs and the risk factor (Gaughan, 2015).

The right contract matched with the correct procurement should be determined before starting a project by the contracting authority, and Irish and EU procurement regulations should be followed in the

project's procurement procedures (McAuley & Lefebvre, 2019). Tendering is a part of the procurement procedures, according to McAuley and Lefebvre "The EU and national procurement rules state that winning tenders should be chosen as Most Economically Advantageous Tender (MEAT) or best price-quality ratio'' (McAuley & Lefebvre, 2019). However, it has been argued that the contractors should be selected based on best value as opposed to lowest cost (Gaughan, 2015).

In 2004, the European Parliament issued a directive on the procurement of all public works contracts entitled 'The coordination of procedures for the award of public works contracts, public supply contracts and public service contracts. The introduction of the European Directive caused implications on the tendering process such as time limitations for tenders' submission and value for money rather than cheapest bid (McAuley & Lefebvre, 2019). Thus, as a result of this directive the Irish government established the Public Procurement Reform initiative, which provides the necessary policies and contracts for the procurement of general work in Ireland through the Capital Works Management Framework CWMF (Gaughan, 2015). The objectives for the CWMF are to ensure greater cost certainty at the award stage, better value for money at all stages and more efficient end-user delivery (Public Procurement Reform, 2005). Many publications have shown that the introduction of Procurement Reform has led to the introduction of cost certainty during the construction process (Gaughan, 2015). However, it was argued that the objectives of the CWMF were not achieved (McAuley & Lefebvre, 2019). Nevertheless, Dunne (2009) believes that 'cost certainty is being achieved' since the introduction of the new GCCC (Government Construction Contracts Committee) construction contracts (Gaughan, 2015).

For the purpose of improving project delivery, BIM was introduced in the Irish construction sector (Stewart, 2015). Eastman and other authors have suggested that a collaborative procurement route must be used for BIM to maximise its potential benefits (McAuley & Lefebvre, 2019). McAuley & Lefebvre argue that the current procurement methodologies are seen as one of the barriers to collaborative working (McAuley & Lefebvre, 2019), showing that there is a call to change the traditional procurements. Love et al. (2012) argue that the separation between design and construction processes in the traditional procurement contribute to creating a gap that inhibits communication, coordination, and integration among project team members and can adversely affect project performance (Love, et al., 2012). The traditional method can be a barrier to innovative change as this method does not engage all project's stakeholders at the same time at the early stage of the project (McAuley & Lefebvre, 2019). The full benefits of BIM cannot be achieved under the traditional method (Salmon, 2012). However, according to the National Construction Contracts and Law Report issued in 2018, it has been detected that traditional procurement is still the most used in the UK (46% of projects) (NBS, 2018).

Gaughan has argued that there is a need to reform public work procurement to be more collaborative as cost certainty was practically limited, and it has been suggested that the methods that best promote collaboration are Project Alliancing and Integrated Project Delivery (IPD) (Gaughan, 2015). The characteristic of these approaches, which is considered key to successful use of BIM, is involving all stakeholders including contractors (Alhusban, 2018). The Early Contractor Involvement (ECI) featured with improving relationships and collaboration between parties, increasing buildability, reducing risks, saving costs, early completion of the project, thus overall better value for money (Wondimuab, et al., 2016). ECI is seen as more suited to complex projects. However, implementing ECI requires "fundamental change of attitude and organisational culture" (McAuley & Lefebvre, 2019).

The types of public contracts used in Ireland are clarified in Figure 1. One of them, PW-CF10, was designed for the early collaboration in large complex projects (McAuley & Lefebvre, 2019). Forms of public contracts have been criticised for discouraging collaboration (McAuley & Lefebvre, 2019). The Society of Chartered Surveyors Ireland conducted a review in January 2014 on the new GCCC construction contractors, and declared that there was an 'unfair transfer of risk to contractors' (Gaughan, 2015).

Nature of Works	Contract Type	Code	Form of Contract
Building Works	Traditional	PW-CF1	Public Works Contract for Building Works designed by the Employer
	Design-and-Build	PW-CF2	Public Works Contract for Building Works designed by the Contractor
Civil Engineering Works	Traditional	PW-CF3	Public Works Contract for Civil Engineering Works designed by the Employer
	Design-and-Build	PW-CF4	Public Works Contract for Civil Engineering Works designed by the Contractor
Minor Works, Building and Civil Engineering	Traditional	PW-CF5	Public Works Contract for Minor Building and Civil Engineering works designed by the Employer
Short Form, Building and Civil Engineering	Traditional	PW-CF6	Public Works Short Form of Contract for Public Building and Civil Engineering Works
Investigation , Building and Civil Engineering	Traditional	PW-CF7	Public Works Investigation Contract
	Traditional	PW-CF8	Public Works Investigation Short Form of Contract

Nature of Works	Code	Form of Contract
Framework Agreement	PW-CF9	Public Works Framework Agreement
Large projects (e.g. over €100 million), or technically complex projects on which Contractor input is required at an early stage	PW-CF10	Public Works Contract for EARLY COLLABORATION
Urgent maintenance requirements or where certain types of planned maintenance and refurbishment are envisaged	PW-CF11	Public Works Term Maintenance and Refurbishment Works Contract

Figure 1: Forms of public contracts (Reform, 2018).

b) The Innovative International Project Delivery Strategies Including BIM, Lean and IPD

To understand the effects of innovative project delivery strategies, it is necessary to identify them along with their synergies.

The BIM concept was introduced in 1970. Starting from the mid-2000s, BIM technology was gradually developed and practically used in the AEC industry for projects as a solution to industry ineffectiveness. The USA was the first country to implement BIM. Nowadays, the European construction industry prevalently uses Building Information Modelling (BIM); however, it was introduced late into the Irish construction sector. McAuley (2012) believes that using BIM may assist in obtaining cost certainty throughout the public works sector, where the mass model studies let the design teams design to a cost, rather than cost to design (Gaughan, 2015).

BIM can be defined as "a digital representation of physical and functional characteristics of a facility". It is a process that gives the insight and tools to the Architecture, Engineering, and construction (AEC) sector to design, construct, and manage buildings efficiently; it provides the information as a 3-dimensional visual model of the completed facility, improving the decision-making and consultation processes, and reduces the potential for changes that often must be made during the construction phase (Sacks, et al., 2017). Various authors have underlined the effectiveness of BIM. It has changed the way of working in the AEC industry and transformed the roles of the project stakeholders; it has various software that enabled the project team members to collaboratively work on one single model to ensure constructability (Dave, et al., 2013), and revealed the clashes among the multidisciplinary models which can be addressed before working onsite (Alhusban, 2018). Getting better quality buildings at lower cost, reducing project duration along with reducing the waste because the material quantity needed is more accurate positively affects the project, and overproduction is not expected (Dave, et al., 2013).

The interactions between BIM and Lean were pointed out by Sacks and other authors (Sacks, et al., 2017). The concept of Lean was established in the 1950s. Lean construction is a philosophy based on the concepts of Toyota Production System (TPS), it is all about continuous improvements to deliver profitably the needs of the customer (A.H.Fakhimi, et al., 2016). The thinking behind Lean is improved processes that need less human effort and cost, less time to make products and services with best quality and minimum faults at a lower cost and increasing the value to the customer; these processes also increase productivity and reduce waste (Sacks, et al., 2017). BIM and Lean have similarity in their aims (Ismail, 2019). BIM technology is used to detect clashes in the virtual models, get accurate material quantity (auto take-off instead of manual take-off), and track the materials delivery status by using 4D simulation. The cost of the project can be tracked thanks to schedules which can be issued automatically at any stage of the project, so any specific data can be issued to the right persons at the right time. Therefore, the performance of the projects is improved (Dave, et al., 2013). It is argued that BIM technologies and processes can achieve outcomes according to the Lean thinking principles.

The traditional procurement is considered by some as an obstacle to properly implementing Lean and BIM (McAuley & Lefebvre, 2019). According to Holzer, IPD is the most suitable approach in the context of BIM (Holzer, 2015). Lean and IPD have similarity in their goals (Alhusban, 2018), to the point that Mossman and other authors do not recognize a distinction between IPD and Lean so that they introduced a combined name for their collaborations, Lean Integrated Delivery Project (LIPD) (A.H.Fakhimi, et al., 2016).

IPD is defined according to the AIA (American Institute of Architects) as "a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste and maximize efficiency through all phases of design, fabrication and construction" (Stewart, 2015). It was first delivered in the US in 2007, with initial case studies collected and dissemination in 2010 (Ismail, 2019). The strategy of IPD is to bring all participants together early with collaborative incentives to maximize value for the project. Many researchers believe IPD has parallels with the Lean construction movement, which has aimed to translate product manufacturing and production methods to construction (Ismail, 2019). By looking at the IPD approach, there are around six characteristics that differentiate it from traditional project delivery: a multilateral contract, early involvement of main participants, collaborative decision making and control, shared risks and rewards, liability waivers among key participants, and jointly developed project goals. AIA explains that, achieving the benefit that IPD offers requires the participants of the project to follow some key important principles such as mutual trust, mutual reward, early involvement of key participants, early goal definition and leadership (A.H.Fakhimi, et al., 2016).

Many publications have suggested that the understanding of BIM accelerates, but procurement processes that are rooted in a pre-BIM world make the true efficiency gains of BIM limited. Many authors say that the transformation of traditional procurement processes can truly unleash the efficiency savings, which can be achieved by openly-shared project information models (Alhusban, 2018). It was concurred that IPD is the most suitable approach in the context of BIM (Alhusban, 2018). However, the process does not finish with signing an IPD or a partnering agreement between companies, the real

challenge is to make these companies' staff work as one team daily. The lean operating system is necessary to make this happen. Technologies such as computer modelling of BIM are vital catalysts as well, as they enable transparency and promote shared understanding (Zimina, et al., 2012). In an AIA document, it was stated that "although it is possible to achieve IPD without BIM, it is the opinion and recommendations of this study that BIM is essential to efficiently achieve the collaboration required for IPD" (Alhusban, 2018).

Cooperation between the different parties involved in the project and supporting the project through its lifetime in the design, construction, fabrication, procurement, and maintenance phases emphasized by Lean and IPD, can be facilitated by BIM concept (A.H.Fakhimi, et al., 2016). However, the implementation of these strategies is a challenge; the following points sum up the challenges.

- Cultural barriers, this refers to the unwillingness of the industry to vary from its traditional method.
- Legal barriers, the lack of procurement and contract that utilise the trilateral innovative strategies, enhance collaboration, and reduce the ability of project stakeholders to sue one another.
- The level of understanding the tools and effects of these innovative strategies, some of these strategies are still new for some people in the Irish public works industry.

c) The Impact of Lean, BIM and IPD on a Large Complex Public Project

Previous publications have confirmed that multi-disciplinary collaboration has a positive effect on a construction project throughout its lifecycle. While Lean, BIM and IPD are independent processes which add separate value to a project, their synergies are more effective to ensure high levels of collaboration and thus ensure a more focused integrated project team, improvement of both constructability and cost certainty, as well as better risk management (Ismail, 2019). Bilateral and trilateral synergies of these international strategies have been used in large complex public construction projects globally. Empirical studies have been conducted on how to use these strategies to save time and money by exemplifying some results achieved by avoiding conflicts, satisfying clients' needs, and adhering to schedule and budget (Andersen, et al., 2012).

Figure 2 shows a schematic overview of practices and effects of lean construction in various projects (Andersen, et al., 2012).

Author(s)	Studied at/by	Practices	Effects
Garrett et al., (2011)	Anonymous	A lean tool, value stream mapping (VSM), and various other lean concepts were used, electronic versions of the submittals	Part of the coordination effort was eliminated. Activities in the process were reduced from (8 to 5), decrease lead time (40%) and process time (25%). E-copies affected review time of the submittal.
Miletsky, R.J., (2010)	Association General Contractor of America (AGC) forum	Involvement of workers.-Three dimensional software, Models,-Direct contact between management, Immediate address worker issues	Can show the work progress, interested in their work, positive effect on workers and workers morale and employees can list their concerns and problems.
Yoders, J., (2009)	Turner Construction CoTennessee Medical Center.	Building information modelling (BIM)	- Reduction in cost from estimated at $286 million by $3 Million,
		+ Lean Construction	- Shortening the delivery time.
Ballard, B., (2008)	-Shawano Clinic	The Lean Project Delivery System	- Target cost was set 3.6% below benchmark; actual cost was 14.6% below target, and 17.6% below the benchmark. Project was completed 3.5 months ahead of schedule, generating 70 additional day's revenue for the owner ($1 million.)
	- ARC for Sutter Roseville Medical Center and the Fairfield Medical Office Building for Sutter Fairfield		- Target cost ($18.9 million) was set 14.1% below the benchmark ($22.0 million). The actual cost ($17.9 million) for the original scope under-ran. The target by 5.3% and under-ran the benchmark by 18.6%
Alarcon, et al., (2006)	Over 100 projects in Chile	Last Planner System and other Lean Construction techniques in over one hundred construction projects for five years.	- 7% to 48% performance improvement were reported by 8 companies
			- Improve reliability of planning and PPC.
			- IT tools can support a more complete and standard implementation of LPS
Richard, H., (2007)	-Boldt Co.	-Adapting Toyota motors principles - Applying software to front end design to spot conflicts Use scheduling LP, select subcontractors based on experiences, JIT	- Boldt co. met the client's needs for $2 per foot less than budget,
Salem, et al., (2005)	Garage project	Implementation and Assessment of Lean Construction Techniques/tools: Last Planner, Visualization, Daily Huddle Meetings, First Run Studies, The 5s Process, Fail Safe for Quality and Safety	Last planner, increased visualization, daily huddle meetings, and first run studies achieved more effective outcomes than expected.-5s process and fail safe for quality did not meet the expectations.
	GC, SubA, SubB		
Conte, ASI et al., (2001)	Construtora Hernandez and the Gerona building	LC production mgt. model deployed; surplus workers/hour for unscheduled activities, Systematic reduction team size	Reduction of the expected construction time and cost by 20% to 30% and 5% to 12% respectively.
Wright, G., (2000)	Boldt Co. and Wisconsin contractor	- Expanding lean application to several projects to boost productivity	- More suppliers involved and becoming supply management too
	Hewlett-Packard	-Fast- track and high-tech	- The project was delivered for $3 Million although the budget was $4.5 Million
Viana, D.D., (2011)	Two anonymous cases	Application of LAP and LPS	Misunderstandings of some LP ideas, two-way communication plays a key role

Figure 2: A schematic overview of practices and effects of lean construction in various projects (Andersen et al., 2012).

d) *Case Study*

According to a performance assessment study of 957 projects (average project size $65MM) by the U.S. Construction Industry Institute, only 30% of projects meet or exceed their cost and schedule goals. However, from 2007 to 2019, Sutter Health has a 92% success rate, with 25 completed projects at a cost of $4.7 billion, 5% under budget while the project delivery in the world has a 70%+ failure rate (Christian, 2020). Therefore, one of the successful experiences to overcome the overruns and ensure cost certainty is Sutter health. Sutter used BIM, Lean and IPD to address problems of budget and schedule overruns occurring in many of their projects (AIA, 2012). Since the case study of the Sutter medical office building, US, specified BIM within the IPD contract and Lean methods, and ensured the alignment of all project's participants, it will be investigated (Ismail, 2018). The project description is presented in Figure 3 (Ismail, 2018).

Figure 3 Sutter medical office building, project description (Ismail, 2018).

This was a $19.4 million, three-story medical office building housing primary care medical offices and laboratories.

By reviewing the coordination strategy, the main stakeholders in this project represented by Sutter Health and Sutter Health Medical Foundation. They involved the main design-build subcontractors early in the design phase. It is noted that the preconstruction design enhanced the participants' workflow that had the biggest effects on systems such as electrical, mechanical, and plumbing along with external facade/glazing sub-contractors, where the collaboration was increased and coordination inherent to IPD resulted in an increased number and frequency of meetings.

The coordination was made using tools such as BIM technology and Lean tools including the Last Planner System and a big room where group coordination sessions were held; thus, these sessions enabled many clashes to be identified and provided cost savings due to increased collaboration and communication with accurate scheduler and less re-design (AIA, 2012).

Sutter Health has long been a supporter of Lean and IPD, by reviewing Sutter health experience, it is realised that it is all about the people. It is stated by David Marquet that Lean projects were often successful when the leaders allowed others to step forward with information, expertise, and ideas of their own. This helps create a culture of trust that allows for continuous improvement in an atmosphere of healthy competition, as everyone is willing to try new behaviours and new types of engagement. When everyone on the team—an architect, engineer, or contractor—feels able to share what they know, a culture of creativity and innovation will be fostered, which is needed to have a high-performing team (Hetherwick, 2018). Thus, the best collaboration takes place when all participants see themselves as being equally involved in the process (Lichtig, 2005).

By observing the contractual agreement used, the Integrated Form Of Agreement IFOA was implemented, which is a multi-part contract between the owner, the architect and builder. Each party was held accountable to each other as equal partners. The Architect and the builder were jointly responsible for construction errors and design omissions. Hence, the contract created a system of shared risk with the goal of reducing the overall project risk rather than passing risks between parties. The project participants jointly controlled the contingency funds. This contract was the first of its kind to be used on a construction project in the US (Ismail, 2018). As a result, IPD has significantly improved trust between trades and eliminated contingencies (AIA, 2012). Thus, by aligning the owners' commercial goals with those of the project team it was possible to create a win-win situation where any incentive became an acknowledgment of a job well-done.

The lessons learned from this study were Sub-contractors felt that more efforts were required up-front compared to traditional delivery system, but the benefits of this up-front effort and collaboration are agreed by all participants, and rework was almost fully eliminated. In addition, having skilled people onsite with BIM software to check progress and immediately find solutions to arising problems was beneficial.

The design team felt that the owner had to be kept engaged from the earliest design stages and throughout construction as well as all participants, to enable quick decision making by the owner, which means less delays on the project. However, several sub-contractors did not want to attend scheduled group meetings, and IPD philosophy faced resistance.

V. QUALITATIVE ANALYSIS AND SYNTHESIS OF INTERVIEW FINDINGS

In order to have more comprehensive view about using BIM, lean and IPD to deliver a large complex public project in Ireland in terms of cost certainty, semi-structured one-to-one in-depth interviews were conducted. The participants selected were all working in senior positions in their organisations with experience in public works in Ireland, and they were chosen for involvement in the innovative project's delivery strategies; their knowledge in this area exceeds 20 years. The interviews were carried out to investigate the current situation in the real world in terms of the research question. According to Boyce & Neale "In-depth interviewing is a qualitative research technique that involves conducting intensive individual interviews with a small number of respondents to explore their perspectives on a particular idea, program, or situation" (Boyce & Neale, 2006). Semi structured interviews allow for open-ended responses from participants for more in-depth information. It gives informants the freedom to express their views in their own terms and allows respondents time to open up about sensitive issues; thus, semi-structured interviews can provide reliable, comparable qualitative data (Adams, 2015). NVivo software was used to convert all interviews to transcripts, and to assist with the analysis of the interviewees' transcripts (Alhusban, 2018). A word cloud generated of the frequently occurring words in the data is represented in Figure 4.

Figure 4: A word cloud of frequently occurring words in the interviews (Author's own, 2021).

Benefits, barriers, and challenges which had been extracted from the literature review regarding BIM, Lean and IPD would be evaluated by the interviewees. Recommendations will be suggested to increase the cost certainty in the public procurement in Ireland from the interviewees' perspective.

All interviewees are anonymised to protect their identity and confidentiality. Each interviewee had been coded as Participant (P). A set of questions has been created to achieve the objective of the research; the same questions had been presented to the interviewees. More additional questions have been designed for each participant based on their background. Table 1 lists the interviewees.

Table 1: Interviewees' list.

Name	Company	Role
P1	Tier 1 Contractor	Digital Construction Operation Manager
P2	Irish Construction Industry	Senior Specialist Contracting
P3	International Support Services Company/Dublin City Council	BIM Manager/Head of Estimating Department

As observed in the literature review, all participants support the idea that BIM, Lean, and IPD are methodologies can benefit projects in the Irish public sector in terms of can increasing collaborative work and ensure cost certainty. but they face challenges in their implementation.

All participants were asked about their assessment of the current public procurement in Ireland, and whether the cost certainty was achieved.

"The Irish government embarked on an initiative to reform public procurement to ensure better cost certainty at tender award stage, better value for money (VFM), and more efficient delivery of public works projects" (Public Procurement Reform, 2005).

The arguments by P1 and P2 are supported by McAuley and Lefebvre (2019), they argue that the current procurement methods in the public Irish sector are seen as one of the barriers to collaborative working and do not achieve better cost certainty (McAuley & Lefebvre, 2019). P1 described the current forms of public procurement within Ireland as out-dated\ and problematic. And they do not necessarily represent best value for money for the Irish people in terms of the procurement methodology. However, Dunne (2009) and P3 argue that the public works contracts are devised so the cost certainty can be achieved (Gaughan, 2015). P3 tends to find that the public works sector is well designed; however, the process is very slow compared to the private sector. his is one of the reasons for the housing crisis, because things are slow, but they are thorough.

Guahan (2015), P1 and P2 concur that the current contract framework for public works in Ireland that was put in place is a strict form of contract that tries to pass all the risk to the contractor (Gaughan, 2015).

Gaughan (2015) and P1 argue that the contractor should be selected according to the best value, not according to MEAT (Gaughan, 2015). P1 pointed out that the people responsible for the current forms of public contracts would suggest that it is based on the most value for the Irish person because it is generally centred on MEAT. However, this is a persistent challenge for the contractor, due to the expectation of the contractor having a fully designed project. However, in fact there are errors and omissions in the design. While the government points to MEAT figures as competitive figures, these contracts have a lot of claims against them, and the figures tend to be higher than what was tendered initially.

The participants were asked if BIM, Lean and IPD are considered as factors of cost certainty in Ireland.

Dave et al. (2013), and all participants believe that BIM should contribute to the cost certainty because it is a process for creating and managing information on a construction project across the project lifecycle based on a 3D model and it aims for better quality buildings at lower cost and reduced project duration (Dave, et al., 2013). However, Gaughan (2015) and P1 observed that BIM, Lean and IPD would not be cost certainty factors; because public procurement in Ireland is not currently taking them seriously since they are not widely used.

Montague et al. (2015) and all participants concur that one of the most important benefits of BIM

technology is clash detection or clash avoidance, because changeovers and anomalies will be avoided on the physical site. In contrast with using the traditional strategy; it would not have been fully designed, could be changed onsite which leads to cost overruns, delays, and this would lead to a lot of issues and compensation claims (Montague, et al., 2015).

The argument by P2 is in line with McAuley & Lefebvre (2019), they asserted that early involvement of all stakeholders is considered key to successful use of BIM. P2 concurs that the contractors need the engagement of the supply chain because that is where the design information and the constructability reviews come from; it is important to receive that information at an early stage of the project.

Packman (2018) and P2 agreed that BIM provides us with the opportunity to define the Asset information requirements from the outset (Turner, 2019). BIM provides an understanding of what exactly the asset is, and allows people to analyse it including the people who want to manage, use, and build it. All those people have a chance to assess the asset before it is physically built.

Sacks et al. (2017) and all participants support the idea that Lean can increase cost certainty. The Lean system focuses on continuous improvements and respect for people. Lean approach is about improved processes with less human effort, less cost, increased productivity, reduced waste, and less time; to make products and services with best quality and minimum faults at the lower cost that increase the value to the customer (Sacks, et al., 2017). It is realized that Lean and BIM have shared goals (Dave, et al., 2013). P2 shared his experience in the company where they adopted BIM, Fabrication, Lean, to digitally build the model virtually, then fabricate it offsite and use lean onsite to drive efficiencies and keep people working together. They achieved cost reduction and waste elimination.

Stewart (2015), P1 and P2 agree that IPD is an interesting concept because it increases the collaboration and the transparency among the stakeholders, and it allows them to share the risks and rewards (Stewart, 2015). However, P3 notes Ireland has not done very many IPD contracts, and usually IPD is only done for contracts over one hundred million or very complex contracts. The usual projects in Ireland are not big enough or complex enough to use it. There are 11 types of contracts, one of them, PW-CF10, is for early collaboration. P3 concurs that IPD has never been used in the Irish public sector.

By looking at the technologies provided by BIM and the principles provided by Lean along with the legal agreement that are presented by IPD, all those approaches enhance collaboration. Ismail (2019) and all participants firmly believe that trilateral constituent parts are critically important to improve project delivery in Ireland in terms of cost certainty (Ismail, 2019). P1 confirmed that in his company they found a cost reduction when using BIM and Lean methodologies, especially by using a blended approach, where BIM technology enabled Lean principles. P1 gives an example according to his experience in private projects such as Intel in Leixlip; he assessed the environment as fantastic and really pioneering. It is a good example of where the trilateral synergies BIM, Lean and IPD were successfully blended, and great results were achieved in the project. In addition, using those methodologies brings tremendous focus, people tend to focus on the issues and solve it together, and learn how to work better collaboratively.

The participants were asked whether the methodologies BIM, Lean and IPD are equally effective on the project, or some methods are more effective than others.

Alhusban (2018) and P1 argued that BIM is a basic tool for Lean, and if they are blended with IPD then the outcome will be great in terms of cost certainty, but P1 confirmed that IPD is not used in the Irish public sector. On the other hand, P2 reported that Lean is currently having a bigger impact because the contractors have moved towards Lean as it improves their efficiency, and IPD would help since it gives more visibility and its synergies keep people work together. But in terms of BIM, the contract authorities in the public side are not advanced enough. They have no idea what to ask for. They would rely on a third party to tell them. In the words of P2, he asked that "what is the point of bringing someone that is not integrated within the capital or asset management team to help you understand what data you use post completion?". However, Sacks et al (2017) and P3 believe in effective synergies between Lean and BIM, because they have similar aims. In fact, architects think about saving costs, and use green products for sustainability rather than thinking about the form of contract or early contractor involvement. So, P3 contended IPD is not at the same level of effectiveness because it is too big a step in the Irish public sector.

The participants were asked about the barriers of the trilateral synergies implementation in the Irish public sector.

a) Barrier: Legal-Contracts

McAuley and Lefebvre (2019), P1 and P2 believe that the current procurement model in the Irish public sector is a barrier to implementing modern construction methodologies that promote collaboration. They described the current contracts as not supporting the innovative strategies including BIM and Lean, because contracts would have BIM but they would not have requirements about lean or IPD. However, Alhusban (2018) and P3 believe that BIM is a collaborative process, and it can be implemented in a traditional contract, where the collaboration within the design team can be achieved. But P3 believes that in terms of all stakeholders, there is no successful proven contract for collaboration purposes in Ireland, and there is lack of trust among stakeholders with the contractors.

All participants agree with Gaughan (2015) that these strategies are characteristic of transparency and collaboration among the stakeholders. Adopting these strategies will be a challenge, because being in specific types of contracts makes the transparency dangerous for stakeholders, they could expose themselves to claims. The interviewees reported that there is no contract framework that allows the use of the IPD model in the Irish public sector, the contracts do not provide shared risk and reward forms, therefore, it is a challenge to direct the client toward that model in the public sector.

Moreover, Zimina, et al (2012), P2 and P3 agree that for IPD to work, people need to trust each other, it cannot be utilised where the parties take an adversarial approach to the contract. Public clients need to trust contractors but that trust and collaboration do not exist. Gaughan (2015) and P3 concur that the existence of a collaborative contract is a fact, GCCC issued PW-CF10 for early collaboration. However, people cannot make valuable decision on this contract because nobody actually used it.

The researcher looked for a public project in Ireland that employed PW-CF10 – but no projects were found that utilised it. Personal communication with CWMF confirmed that it was developed for use on large public infrastructure projects (over €100m only) and for early collaboration. However, it has not been used by public bodies since it was developed. This is primarily because projects of that scale benefit from the participation of contractors outside of this jurisdiction and the use of a bespoke and untried form of contract has been seen by public bodies as a deterrent to international interest. Early collaboration has been used on large public infrastructure projects, most recently the New Children's Hospital NCH and the upgrade works to the Dunkettle interchange. However, The NCH used a bespoke form of contract based upon PW-CF1, and Dunkettle used the NEC 3 target cost contract, in both cases the contractor was engaged post planning approval (Personal correspondence, 2021). P2 believes that the reason behind not using PW-CF10 is because these types of agreements take a long time to be used. In the words of P2, he stated and asked "PW-CF10 can be used but how to keep that person honest?".

b) Barrier: Culture

Ismail (2019) and all participants agree that the main barrier behind adopting IPD is purely cultural and requires a mind-set change (Ismail, 2019). An example provided by P1 concerns an Intel project in Leixlip. When IPD was introduced, there were not many barriers, due to the client being willing to embrace that type of contractual engagement. When implementing BIM and Lean, the biggest challenge faced was the culture, and it was observed that the change management program helped people buy into the change and understand the psychology behind the change. P1 added that establishing a team for construction delivery project to win or lose together makes the perfect sense. But the main barrier is ignoring the potential benefits, therefore, the financial barrier was excluded because these strategies aim at saving time and money, and improving the outcomes for everybody. Although there is cost reduction by using BIM and Lean, a lot of those cost reductions got consumed in in the competitive bidding stage. The cheapest win is not the best, and the contractor hopes that BIM and Lean and similar strategies help to achieve the expected margin within delivery.

c) Barrier: The Level of Understanding of Innovative Strategies

P2 reflects his experience with clients who are hesitant about using BIM in offsite work, the reason behind their hesitation is the requirements listed in the contracts which includes BIM demand, where this level of details or information the clients do not even understand. They do not know what they are asking for. They have just copied requirements from another contract document. So, the big issue is clients do not know what to ask for, how to ask for it. One of the challenges that the contractors face is that they believe in the benefits of BIM, but the Irish government have not made BIM a requirement, in contrast with the UK where the use of BIM was mandated in 2016 (NBS,2017). However, it is widely purported that BIM technologies and processes ensure greater certainty and reduced risk for the client (Montague et al, 2015). Another reason for hesitation about using BIM is when P1 pointed out the problem they face with some of their supply chain members; they still stick to the idea of producing models by using traditional method in AutoCAD, and they consider software such as Revit, Naviswork and Solibri expensive. However, the fact is they do not cost more money than AutoCAD which is an out-dated approach and should be abandoned. P1 and P2 concur that what is required for BIM technologies is skilled people to use them, so skilled people are a vital requirement in implementing BIM. P3 contended that large sectors of people are not yet skilled in BIM, compared with the new generation who use BIM in college. Skilled people are not required only for BIM technology but also for negotiations of IPD, where negotiation skills in normal contracts are different from of IPD's due to the shared risks and rewards. P3 thinks that there are not enough skilled people to actually negotiate in IPD.

VI. INSIGHTS/RECOMMENDATIONS

a) *Public Contracts Need To Be Reviewed*

Gaughan (2015), P1and P2 see that the fundamental thing that needs to be changed is contracts to have a more shared risk and reward type model, and more collaborative forms. P1 added that IPD certainly acts as a catalyst to change the situation.

P2 shared his experience as he is interviewing about 50 different parties investigating how they drive innovation strategies and enhance the development of

the off-site fabrication sector in the Irish construction. The main points from the interviews are the early contractor involvement in the project, having a hybrid contract that allows the contractor to be a part of the design development phase, and finding innovative methods to persuade people to change the present cultural thinking about construction.

b) Change Management Team

Lichtig (2015) and all participants agree that cultural thinking needs to be changed. P1 suggests having a change management team in organisations directed by experts; to learn with them how to deal with different stakeholders, manage vendors, understand what their fears and anxieties and handle them. It is realised that the change of management team is a transformational item for the company. This team had meticulous procedures for stakeholder management process; to persuade them to change the management process and it really worked. Moreover, According to P1, his organisation has an internal system which is used for lessons learned and a whole methodology process on how to share the learning from one project to another to ensure having a knowledge platform. However, P2 shared a different way to persuade the stakeholders to change their cultural thinking, by starting with the contractor's mind-set change. By organising a workshop, like it was in 2013 for people from the M&E sector, and providing a successful example where they adopted innovation strategies such as lean using last planner or value stream mapping on projects. The model chosen was a high-class civil engineering contractor who was using Lean in their projects in the UK. They revealed the reasons behind their change to Lean and clarified why their clients asked them to apply it. This experiment galvanized people to realise that Lean is a serious requirement by clients, and outlined what is needed as a further step. Starting with understanding the language by speaking to clients about it, and how to make mindset of stakeholders gravitate to Lean, as the client should be helped to understand what they need and what they should ask for.

Lichtig (2015), P1 and P2 agree that everyone that is supposed to be part of the process understands why you are trying to do it, what you are trying to do, and then how you are going to do it. It is about that engagement and how it should work.

P3 suggests that people who are in the public sector should enrol in specific courses about innovative strategies; plenty of courses on this topic are provided in the Irish colleges.

c) Making BIM Mandatory in Ireland

McAuley & Lefebvre (2019) and P3 pointed out that the government recognises the need for BIM and they will obviously mandate them in the coming years. Since BIM is not mandated yet, people do not have to engage in it, but they will be once it is being mandated on the public sector contracts, because it means everyone should do it. However, in big project, BIM is used for many public sector projects, because Tier 1 companies who work on those projects use BIM anyway, even BIM is not required on the contract. Until BIM is mandated, it will not be employed in business as the usual methodology. It is still new to many people in the public sector, unless they are doing large projects.

When all participants were asked: To what extent they recommend BIM, Lean and IPD to be sustained or scaled up?

P1 and P2 are extremely enthusiastic about the innovative methodologies including BIM, Lean and IPD. P1 genuinely believes that unless people adopt these approaches, they do not have a future in the Architecture, Engineering, Construction, Operation (AECO) industry; they will be extremely uncompetitive in the next 10 years if they do not adopt those methodologies. P1 and P2 agree that IPD will come somehow once they can convince lawyers to sell it to them, a form of IPD will appear and BIM is found to remain and evolve within this decade. However, P2 believes that Lean is hard to measure, because of a private culture and internal management strategy. However, P3 highly recommends placing more emphasis on lean and BIM by the CIF, which is a construction industry federation to keep on telling people so that they get so used to it. Due to the construction moving towards sustainability and BIM and Lean reduce waste and rework.

When P2 was asked whether any of the methodologies should be discontinued, he answered with the National Development Plan currently, it was originally one hundred and sixteen billion, and it is expected to be raised to 200 billion in July. Thus, the concern attached to that is the capacity in the industry and capability to deliver this scale of projects over 10 years. The public client should look at the efficiencies of BIM, FABRICATION, and the Lean approach and decide to implement all these strategies. The contracting authorities have a major role in driving the change and the industry.

VII. CONCLUSION

The qualitative research has identified theoretical dimensions based on multiple discussions of different authors of the strong synergy between BIM and Lean. The aims of both approaches are linked by the similarity and the combination of having BIM functionality with Lean principles, enhancing the project efficiency and results. Previous research has demonstrated that multidisciplinary collaboration is required to achieve their full potential, early contractor involvement being an essential key to achieve this. IPD is a successful path for the collaboration environment and the goals alignment among the stakeholders of the project. This paper has shown that the contractor believes in the benefits of the innovative methodologies including BIM, Lean and IPD because they make projects more accurate, efficient, and agile leading to better building in a cost-effective manner.

The main purpose of this paper is to identify the barriers to implementing collaborative procurement methods in public works projects in Ireland by appraising its current public procurement, and compiling a review for best international practices.

From the aforementioned US case study, it provides one of the best collaborative platforms, where BIM and Lean are enabled within IPD due to the achieved savings. However, its implementation would be challenging in the current public works context. The procurement feedback concerns about the legal framework and contract types, and a more collaborative model such as IPD is needed to enhance the collaboration and trust among the stakeholders within the innovative strategies. However, the freedom in the public sector to use contracts out of templates is limited. The contracts must adhere to the Irish rules and European directives which are seen as a rigid strategy. This affects the contract flexibility because it prevents public contracts from being tendered outside the approved templates. However, there is the PW-CF10 contract which is designed for early collaboration in the public sector, but it is not tested yet to measure its results; the trial of this contract would be a road map for a form of IPD in public sector, as it can be tested on a public project and its outcome compared with IPD results in the private sector. Therefore, the performance differences between the two contracts can lead to an improved PW-CF10 which can be a European form of IPD. But it should be noted that the client needs to have more willingness to change the traditional strategy to IPD approach. IPD with its characteristic about shared risks and reward, and transparency can be seen as inherently risky. Using IPD requires a change in thinking.

In addition, some of the government departments require the innovative strategies to be applied on their projects and others do not, the reasons behind the different decisions are not clear.

Finally, it is hoped that BIM will be adopted more in the future and mandatory due to the plenty of benefits it has. Reverting to traditional procurement must be resisted because it would go against international trend towards more collaborative procurement methods and contracts. An innovative contractor and a progressive client would lead the change towards expanding these strategies to have more certainty on projects.

VIII. FURTHER INVESTIGATION

Further research is recommended to explore the drivers of the different contracting authorities' decisions and what allows them to take their decisions.

Another direction is to investigate how to put PW-CF10 in action in the public sector to measure its results including the risks and rewards along with the cost certainty, where it can be evolved as a European form of IPD. So, it can be a pathway to find how to increase the flexibility in the contracts within a public procurement regime and how to challenge the norms, because the too prescriptive framework of contract on the public sector stifles innovation.

IX. LIMITATIONS

Due to time-constraints and scheduling issues, the researcher could not include a representation of all stakeholders involved in the procurement of public projects; however, published research and studies by reliable sources had been incorporated.

X. REFERENCES

A.H.Fakhimi, J.Majarouhi & S.Azhar, 2016. How can Lean, IPD and BIM Work Together? In Curran Associates, I., ed. *33rdInternational Symposium on Automation and Robotics in Construction (ISARC 2016)*. Auburn, Alabama, USA, 2016. International Association for Automation & Robotics in Construction.

Adams, W.C., 2015. *Handbook of Practical Program Evaluation - Chapter: Conducting Semi-Structured Interviews*. 04th ed. Wiley Imprint.

Aghimien, D., Aigbavboa, C., Oke, A. & Koloko, N., 2018. *Digitalisation in Construction Industry: Construction Professionals Perspective*. MSc Thesis. South Africa: ISEC Press Sustainable Human Settlement and Construction Research Centre, Faculty of Engineering.

AIA, 2012. *IPD CASE STUDIES*. Case Studies. California : AIA / AIA California Council AIA, AIA Minnesota, School of Architecture –University of Minnesota.

Alhusban, M., 2018. *Conceptual procurement framework for building information modelling uptake to enhance buildings' sustainability performance in the Jordanian public sector*. PHD Thesis. Portsmouth: Ethos.bl.uk University of Portsmouth.

Andersen, B., Belay, A.M. & Seim, E.A., 2012. Lean Construction Practices and its Effects: A Case Study at St Olav's Integrated Hospital, Norway. *Lean Construction Journal*, pp.122-49.

Boyce, C. & Neale, P., 2006. *Conducting in-depth interviews: a guide for designing and conducting in-depth interviews for evaluation input*. Pathfinder International Tools.

Christian, D., 2020. *Integrated Project Delivery*. [Online] (1) Available at: HYPERLINK "https://leanconstructionireland.ie/6016-2/" https://leanconstructionireland.ie/6016-2/ [Accessed 05 January 2021].

Dave, B. et al., 2013. *Implementing Lean in construction: Lean construction and BIM*. Dave, B, Koskela, L, Kiviniemi, A, Owen, R, Tzortzopoulos, P ed. London: CIRIA.

Framework, C.W.M., 2005. *Capital Works Management Framework*. [Online] Available at: HYPERLINK "https://constructionprocurement.gov.ie/" https://constructionprocurement.gov.ie/ [Accessed 10 January 2021].

Gaughan, D., 2015. *Has Cost Certainty been achieved since the Introduction of the new GCCC Construction Contracts?* Dissertation project. Sligo: Institute of Technology, Sligo Institute of Technology Sligo.

Hetherwick, K., 2018. *Making Lean Integrated Project Delivery (IPD) Work*. [Online] Available at: HYPERLINK "https://www.smithgroup.com/perspectives/2018/making-lean-integrated-project-delivery-ipd-work" https://www.smithgroup.com/perspectives/2018/making-lean-integrated-project-delivery-ipd-work [Accessed 10 March 2021].

Personal correspondence, Capital Works Management Framework CWMF, 15 March 2021.

Holzer, D., 2015. BIM for procurement - procuring for BIM. In Crawford, R. & Stephan, A., eds. 49th International Conference of the Architectural Science Association. Melbourne, Australia, 2015. The Architectural Science Association and The University of Melbourne.

Ismail, I., 2018. *IPD & BIM within the Construction Industry*. MSc Dissertation. Ismail, Iftikhar.

Ismail, I., 2019. *Multi-Disciplinary: Integrating IPD, BIM and Lean for efficient Project Delivery*. MSc Dissertation. Manchester: Issue University of Salford.

Lichtig, W., 2005. Sutter Health: Developing a Contracting Model to Support Lean Project Delivery. *Lean Construction Journal*, Vol 2(1), pp.105-12.

Love, P., Edwards, D., Irani, Z. & Sharif, A., 2012. Participatory action research approach to public sector procurement selection. *Construction Engineering and Management*, 138(3).

McAuley, B., Hore, A., Kane, R. & Fraser, S., 2015. Collaborative Public Works Contracts using BIM – An Opportunity for the Irish Construction Industry? In Dublin., S.o.S.a.C.M.a.A., ed. *Proceedings of the 2nd CITA BIM Gathering*. Dublin-Ireland, 2015. School of Surveying and Construction Management, Dublin Institute of Technology,Bolton Street, Dublin 1, Ireland.

McAuley, B. & Lefebvre, F., 2019. An investigation into current procurement strategies that promote collaboration through early contractor involvement with regards to their suitability for Irish public work projects. In McAuley, B. & Lefebvre, F., eds. *4th CitA BIM Gathering*. Galway, 2019. The School of Multidisciplinary - TU Dublin.

Montague, R., Slattery, P., Mockler, J. & Adlem, E., 2015. Managing BIM as an Asset for Building Owners/Operators. In *CiTA BIM Gathering*. Dublin, Ireland , 2015.

NBS, 2018. *National Construction Contracts and Law Reports*. Report. Newcastle, UK: NBS NBS.

Philp, D., 2016. Compliance and Regulation – Building Information Modelling. *Consulting Matters- quarterly publication*, 29 June. pp.20-21. Available at: HYPERLINK "https://issuu.com/consultingmatters/docs/2016_june_consulting_matters" https://issuu.com/consultingmatters/docs/2016_june_consulting_matters [Accessed 01 March 2021].

Public Procurement Reform, 2005. *Construction Procurement Reform*. [Online] Available at: HYPERLINK "https://constructionprocurement.gov.ie/" https://constructionprocurement.gov.ie/ [Accessed 16 November 2020].

Department of Public Expenditure and Reform, 2018. *Capital Works Management Framework Guidance Note-Procurement and Contract Strategy for Public Works Contracts*. GN 1.4. V.1.2. Dublin: Office of Government Procurement Department of Finance.

Sacks, R., Korb, S. & Barak, R., 2017. *Building Lean, Building BIM-Improving Construction the Tidhar Way*. 1st ed. London and New York: Routledge.

Sacks, R., Koskela2, L., Dave3, B.A. & Owen, R., 2010. Interaction of Lean and Building Information Modeling. *of Construction Engineering and Management*, 136(9), pp.968-80.

Salmon, J., 2012. *Wicked IPD procurement programs: IPD & BIM solutions unleashed*. [Online] Available at: HYPERLINK "https://www.augi.com/articles/detail/wicked-ipd-procurement-programs-ipd-bim-solutions-unleashed" https://www.augi.com/articles/detail/wicked-ipd-procurement-programs-ipd-bim-solutions-unleashed [Accessed 10 March 2021].

Sategna, L., Meinero, D. & Volontà, M., 2019. *Digitalising the Construction Sector- Unlocking the potential of data with a value chain approach*. Research. Avenue Milcamps 81030 Schaerbeek, Belgium: Innovation and Development Consulting. Committee for European construction equipment.

Stewart, P., 2015. *An overview of the BIM process from an Irish construction project management perspective*. [Online] Available at: HYPERLINK "http://www.bimireland.ie/2015/10/16/an-overview-of-the-bim-process-from-an-irish-construction-project-management-perspective/" http://www.bimireland.ie/2015/10/16/an-overview-of-the-bim-process-from-an-irish-construction-project-management-perspective/ [Accessed 20 May 2020].

Turner, T., 2019. A Critical Appraisal of the potential for public works contracts' and design-build Clients in Ireland to leverage benefits from BIM processes. In *CITA BIM Gathering*. Galway, Ireland , 2019. CITA BIM.

Wondimuab, P. et al., 2016. Success Factors for Early Contractor Involvement (ECI) in Public Infrastructure Projects. In *SBE16 Tallinn and Helsinki Conference; Build Green and Renovate Deep*. Trondheim, Norway, 2016. Elsevier Ltd.

Xiao, H. & Proverbs, D., 2003. Cost certainty and

time certainty:An international investigation. In J, D., ed. *19th Annual ARCOM Conference*. Greenwood, 2003. Association of Researchers in Construction Management.
Zimina, D., Ballard, G. & Pasquire, C., 2012. Target value design: using collaboration and a lean approach to reduce construction cost. *Construction Management and Economics*, 30 May. pp.383-98.

XI. GLOSSARY

2D: Two dimensional (a flat drawing showing only length and width).
3D: Three dimensional (solid drawing showing length, width, and height).
4D BIM: A 3D model linked to time or scheduling data. Model objects and elements with this data attached can be used for construction scheduling analysis and management. It can also be used to create animations of project construction processes.
A
AE, AEC, AECFM, AECO: Abbreviations for Architect/Engineer, Architect/Engineer/Contractor, Architect/Engineer/Contractor/Facility Manager, Architecture/ Engineering/ Construction/ Operation.
B
Building Information Modelling (BIM): Building Information Modelling (BIM) is a set of technologies, processes and policies enabling multiple stakeholders to collaboratively design,
C
CWMF: Capital Works Management Framework.
Clash Detection: The process of checking for clashes and interferences in the design of one or more BIM models. Also referred to as model mediation.
Common Data Environment or CDE: Process means a combination of hardware, software and workflow that is used to collect, manage, and disseminate all relevant approved files, documents, and data for multidisciplinary teams in a managed process.
CITA: According to Construction IT Alliance.
CF: Contract Form.
D
Design Development: The phase of the design process in which the general relationships Represented in the schematic design phase are resolved in more detail. During this phase The dimensions of all major elements are defined, and forms of construction finalized.
E
F
FAB: FABRICATION.
G
GCCC: Government Construction Contracts Committee.
I
IPD: Integrated Project Delivery
M
Mechanical Electrical Plumbing (MEP): Referring to this group of building services or the engineering disciplines associated with them.
P
PW: Public Work
U
US: United states.